



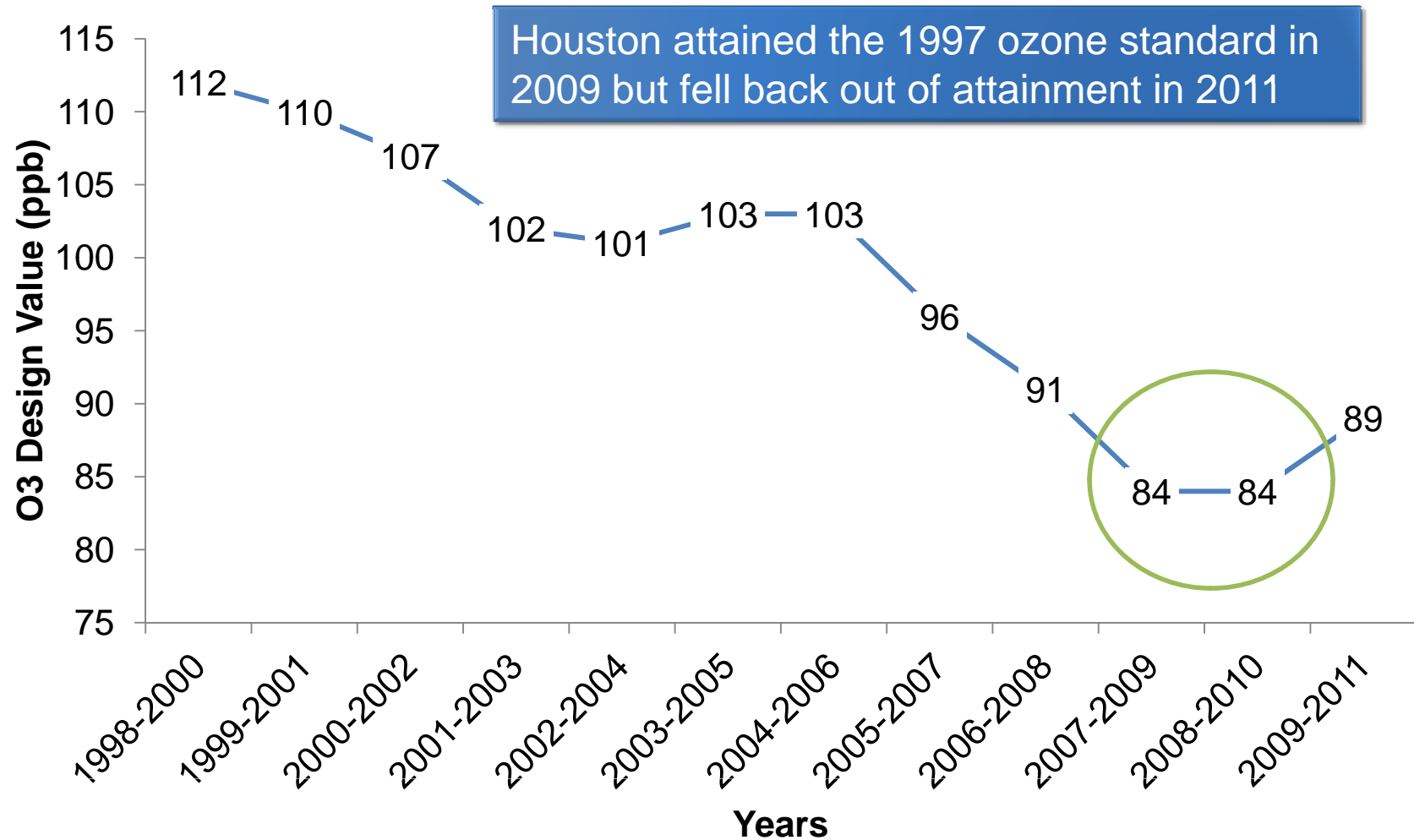
# ESTIMATED IMPACTS OF 2010 WILDFIRES ON OZONE LEVELS IN HOUSTON

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Albert Hendler  
URS Corporation  
Austin, TX

May 16, 2012

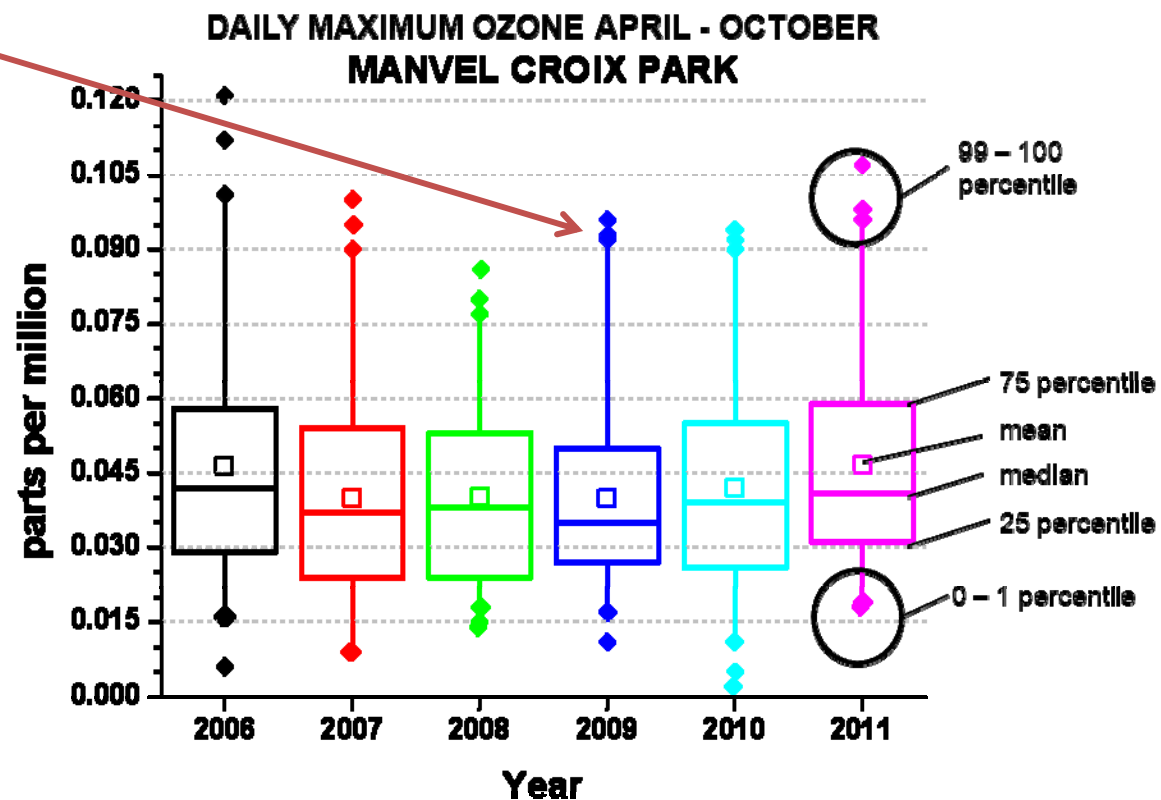
# Houston Ozone Design Value Trend



# Daily Maximum 8-Hour Ozone at the Design Value Monitor

2009 levels were comparatively low, on average, but outliers contributed to 2009-2011 nonattainment (4<sup>th</sup> high was 91 ppb)

Must examine case studies to explain the reversal in the design value trend



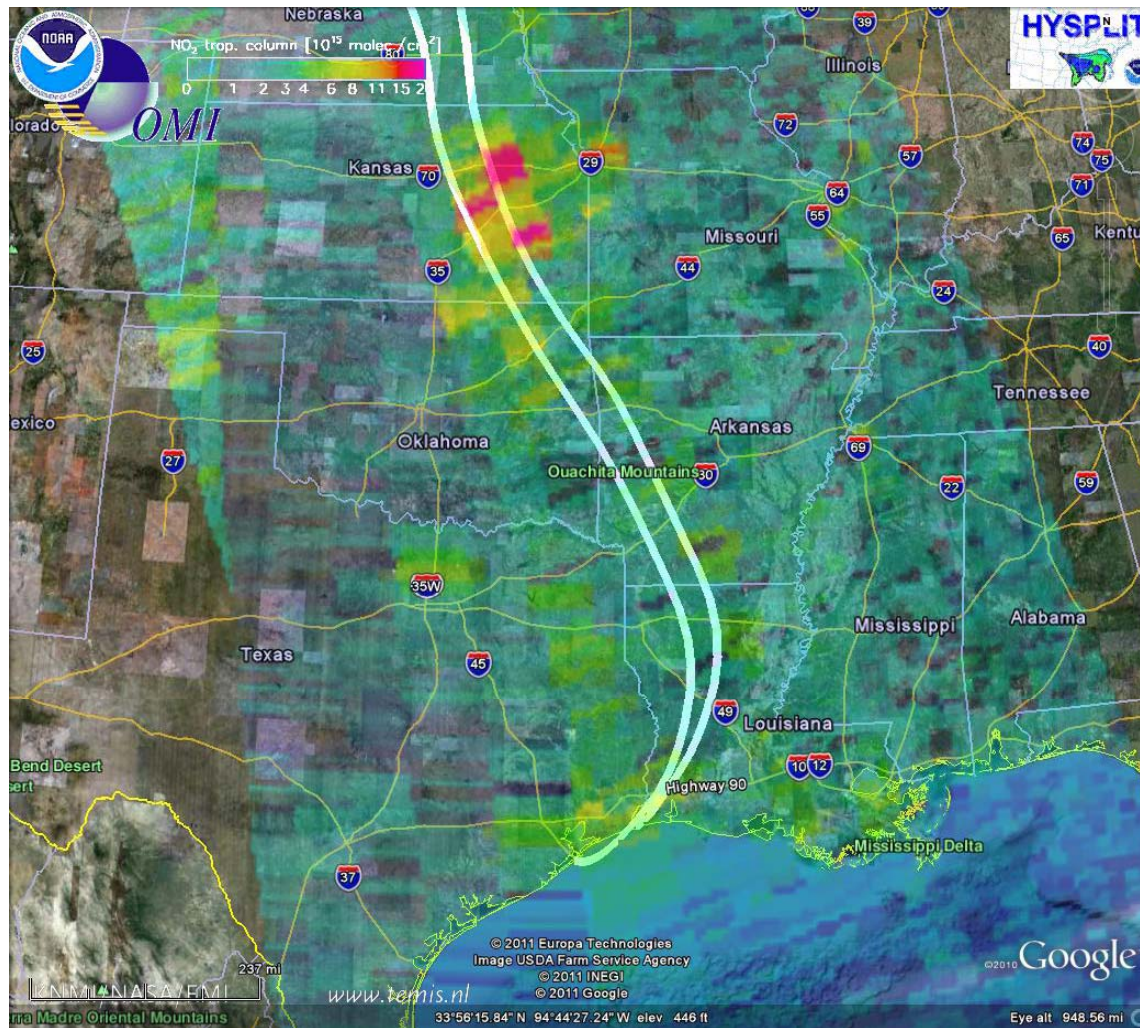
## Smoke from Distant Wildfires was Detected on 3 of the Top 4 High Ozone Days at the Design Value Monitor in 2009

Date	Max 8-Hour Ozone (ppb)	Smoke Description
May 20, 2009	92	Several large fires in western and southwestern Louisiana today ... smoke was drifting westward and southwestward into the coastal areas of Texas.
September 2, 2009	93	...The moderately dense to dense smoke then moved southeastward over Oklahoma, central and eastern Texas, western Louisiana, and over the extreme northwestern Gulf of Mexico.
September 3, 2009	91	Residual light smoke from the same source regions covered the west central Gulf of Mexico, southern Louisiana and coastal Texas.

**Satellite Smoke Text Product from the Satellite Services Division of the NOAA  
National Environmental Satellite, Data, and Information Service (NESDIS)**

[http://www.ssd.noaa.gov/PS/FIRE/2009\\_archive\\_smoke.html](http://www.ssd.noaa.gov/PS/FIRE/2009_archive_smoke.html)

# April 12, 2011 – Flint Hills Grasslands, KS



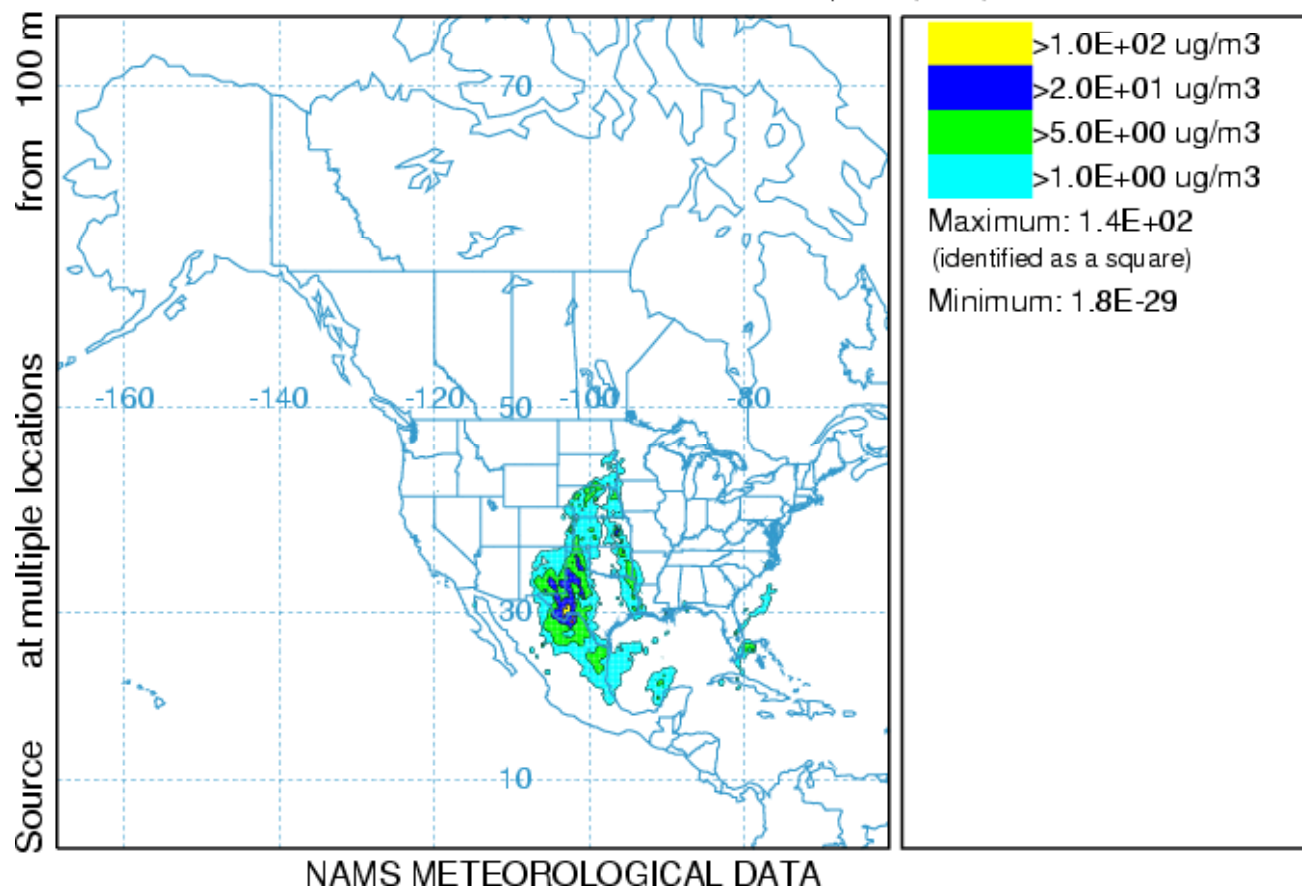


## ARL/NESDIS EXPERIMENTAL SMOKE FORECAST

Air Concentration (ug/m<sup>3</sup>) Layer Average 0 m and 5000 m

Integrated from 1700 12 Apr to 1800 12 Apr 11 (UTC)

PM25 Release started at 0600 12 Apr 11 (UTC)



## Smoke from Distant Wildfires was Detected on 4 of the Top 6 High Ozone Days at the Design Value Monitor in 2010

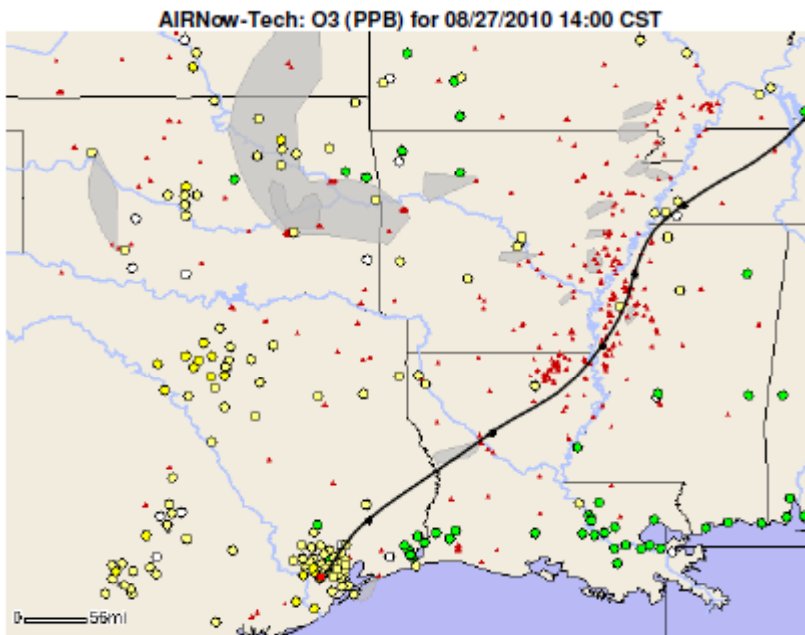
Date	Max 8-Hour Ozone (ppb)	Smoke Description
August 27, 2010	88	Lower Mississippi Valley: Smoke from numerous agricultural fires across the area mixed in with haze from an unknown origin was seen ... slowing drifting to the southwest. This area of mixed aerosols stretches from ..., Louisiana, Texas and out into the Gulf of Mexico.
September 30, 2010	88	A mass of thin density remnant smoke from the previous day's agricultural fires in the Mississippi Valley...moved southward and off the south Louisiana and southeast Texas coast ...
October 1, 2010	86	an area of primarily thin density smoke combined with other aerosols was visible moving offshore over the western Gulf of Mexico. The smoke in this region was believed to be leftover from the Mississippi Valley agricultural burns ...
October 7, 2010	92	A number of smoke producing fires were analyzed across southern Louisiana and far southeastern Texas.

**Satellite Smoke Text Product from the Satellite Services Division of the NOAA  
National Environmental Satellite, Data, and Information Service (NESDIS)**

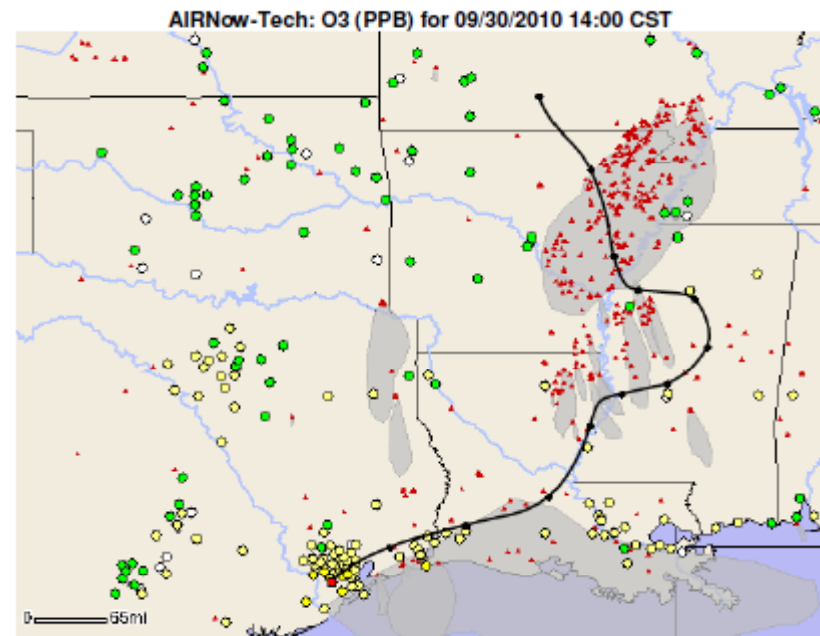
[http://www.ssd.noaa.gov/PS/FIRE/2010\\_archive\\_smoke.html](http://www.ssd.noaa.gov/PS/FIRE/2010_archive_smoke.html)

# Backward Trajectories and Fire Locations on 8/27/2010 (Left) and 9/30/2010 (Right)

August 27, 2010



September 1, 2010

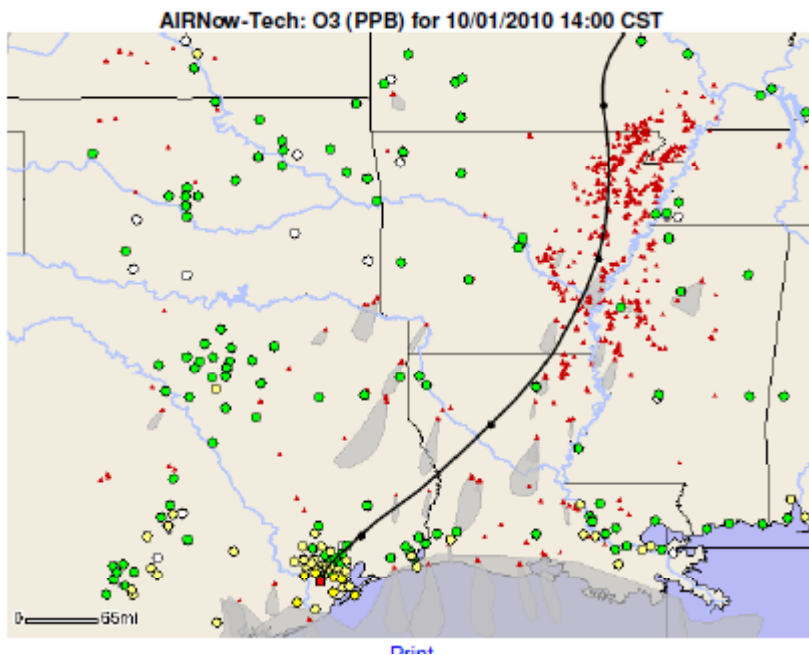


NOAA HYSPLIT trajectories terminating at 300 m above the Manvel Croix Park Monitor at 2:00 p.m. CST on the indicated day. Accessed from [www.airnowtech.org](http://www.airnowtech.org) on October 11, 2010. Yellow circles indicate monitoring sites measuring a 1-hour ozone level above 60 ppb; Green circles indicate monitored ozone levels less than 61 ppb. Red triangles are NOAA HMS fire detects; Shaded areas are NOAA HMS analyzed smoke plumes.

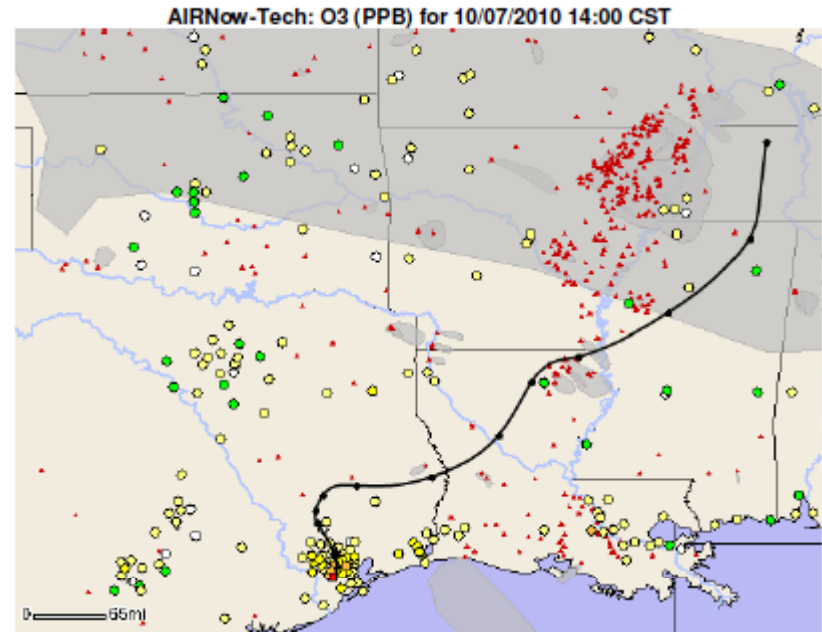


# Backward Trajectories and Fire Locations on 10/1/2010 (Left) and 10/7/2010 (Right)

October 1, 2010



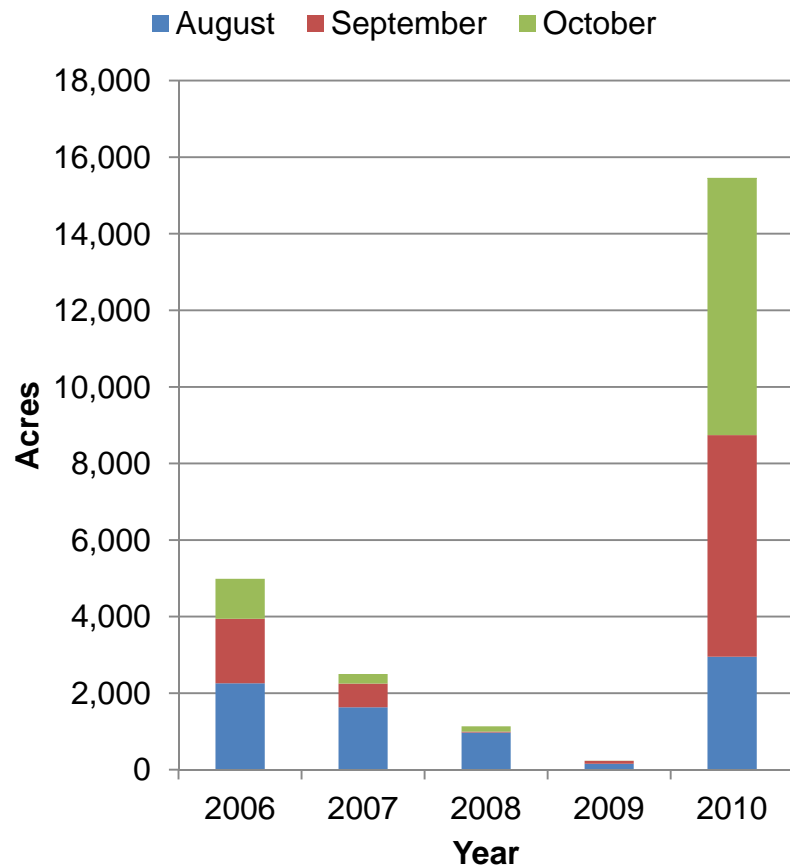
October 7, 2010



NOAA HYSPLIT trajectories terminating at 300 m above the Manvel Croix Park Monitor at 2:00 p.m. CST on the indicated day. Accessed from [www.airnowtech.org](http://www.airnowtech.org) on October 11, 2010. Yellow circles indicate monitoring sites measuring a 1-hour ozone level above 60 ppb; Green circles indicate monitored ozone levels less than 61 ppb. Red triangles are NOAA HMS fire detects; Shaded areas are NOAA HMS analyzed smoke plumes.

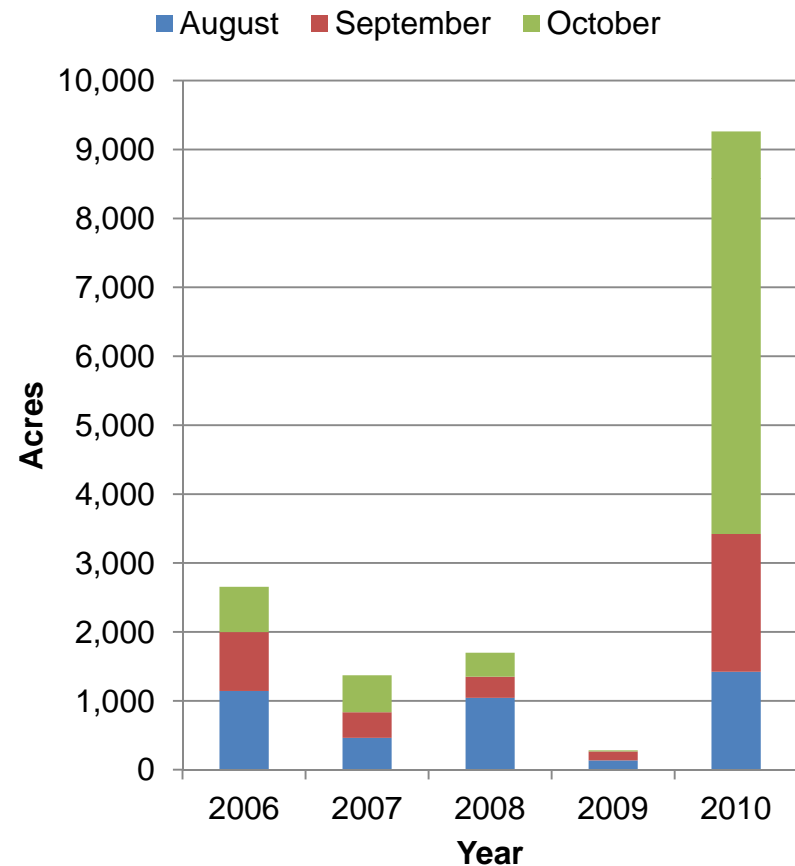
# 2010 was an Exceptionally Active Year for Wildfires in the Lower Mississippi River Valley

## Arkansas Fires by Month



Source: Arkansas Forestry Commission

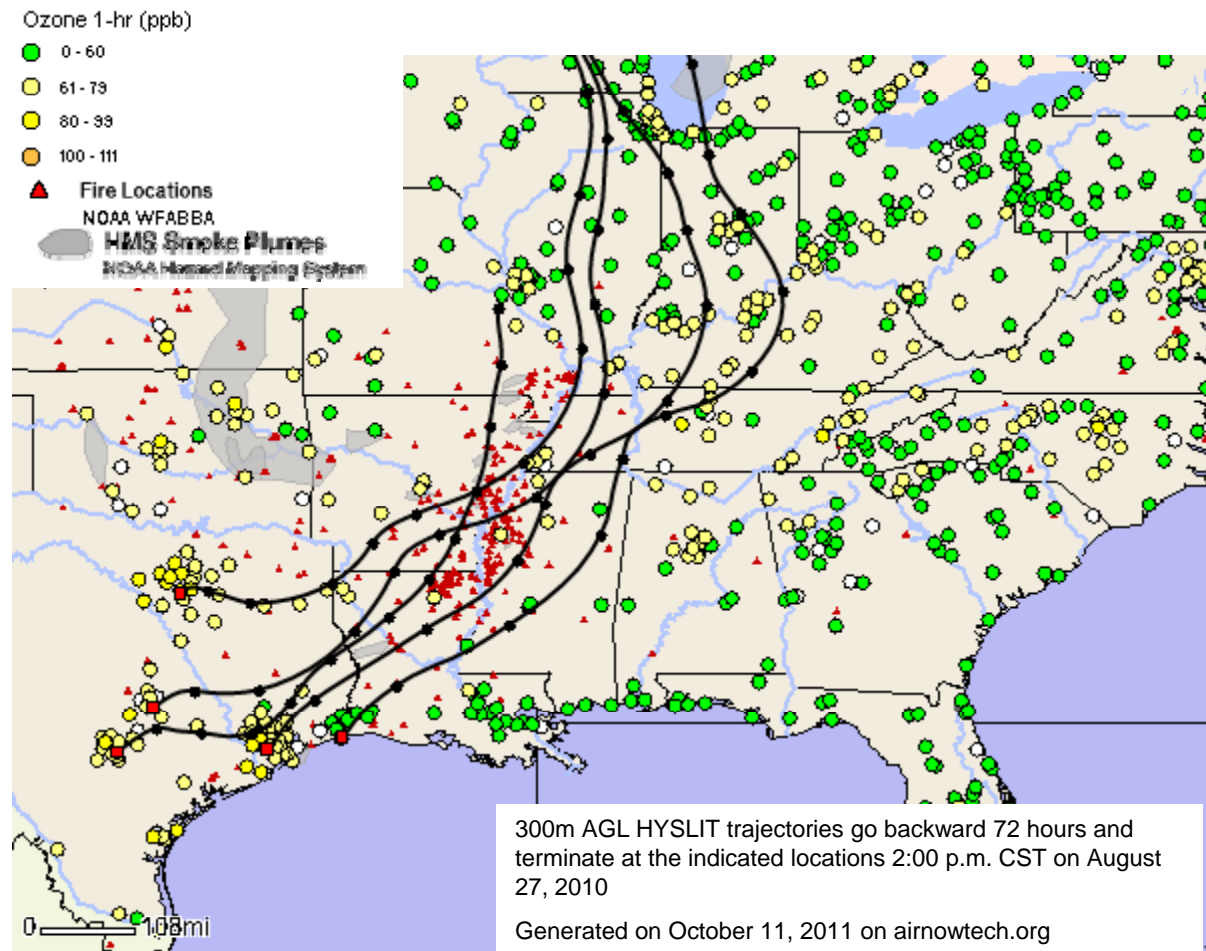
## Louisiana Fire Acres by Month



Source: Louisiana Agriculture and Forestry Commission

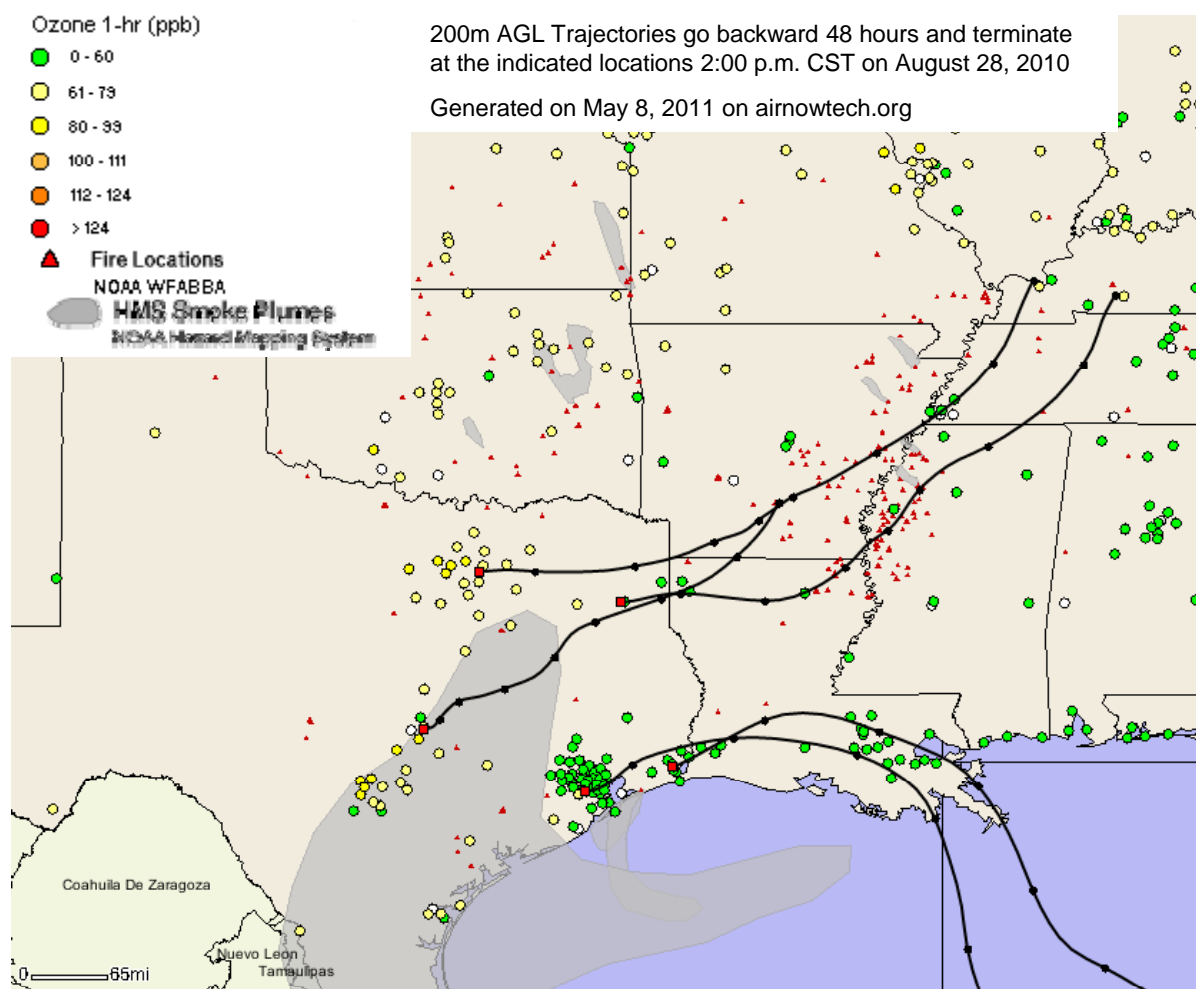
# August 27, 2010 Case Study

- Backward air trajectories from DFW, AUS, SAT and HGB converged near the fires as 24 monitors in central and east Texas recorded 8-hour average ozone levels above 75 ppb.
- BPA trajectory passed through central Mississippi, south of the fires as ozone levels there remained comparatively low.



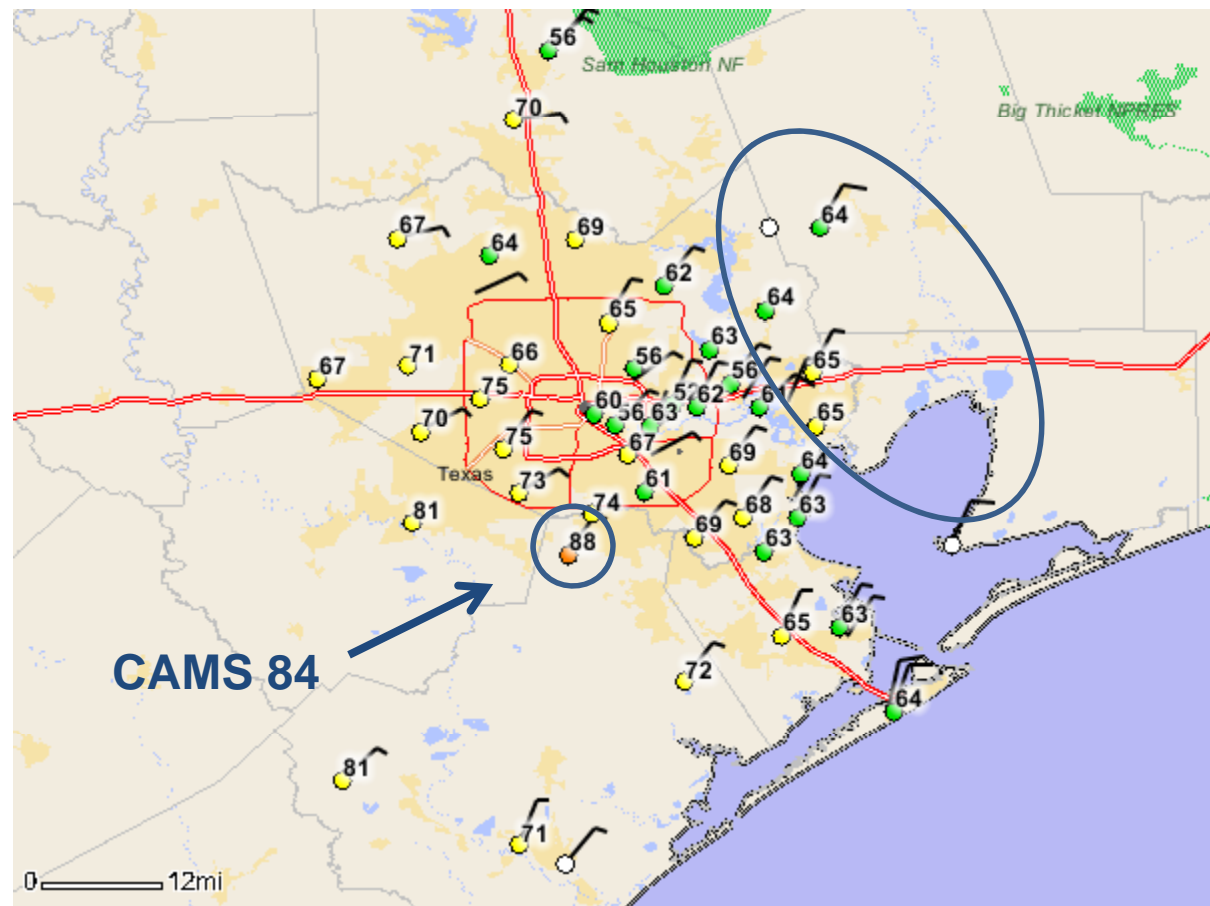
## August 28, 2010 Back Trajectories Curved to the South as Ozone Levels Receded

- Trajectories terminating over DFW and AUS pass through the Lower Mississippi River Valley as daily maximum 8-hour ozone levels exceeded 75 ppb at 15 sites in central and north Texas.
- Trajectories drawn backward from HGB passed south of the fires and ozone levels were comparatively low.



## Ozone Levels in Air Entering the Region in the 8-Hour Period Beginning 9:00 a.m. CST were 64-65 ppb

- The maximum 8-hour ozone level at CAMS 84 was 88 ppb.
- Background ozone levels in the air flowing into HGB from the northeast, upwind of CAMS 84, were about 64 ppb (8-hour average).
- The difference, 24 ppb is likely attributed to production from local emissions.

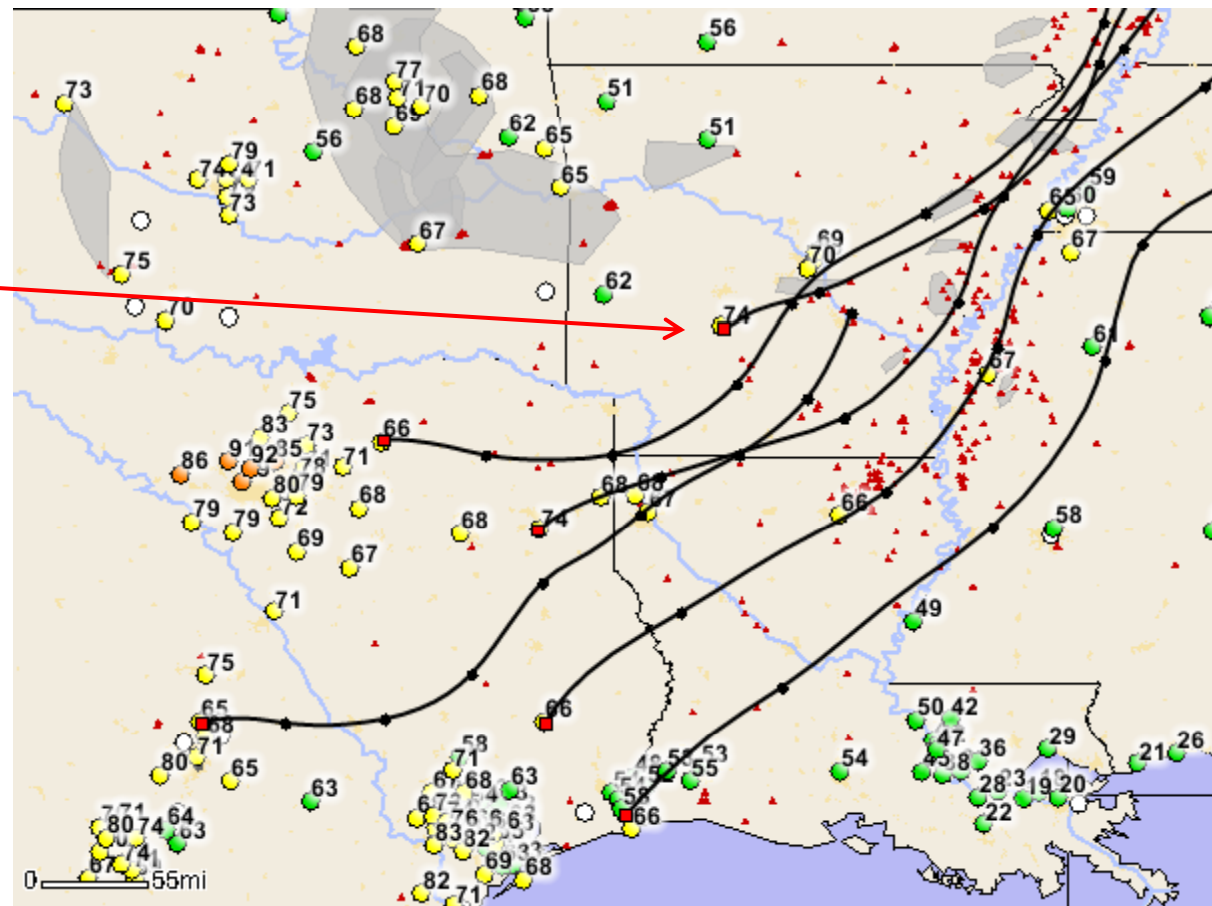




## 8-Hour Average Ozone was Elevated all Along the Back Trajectory

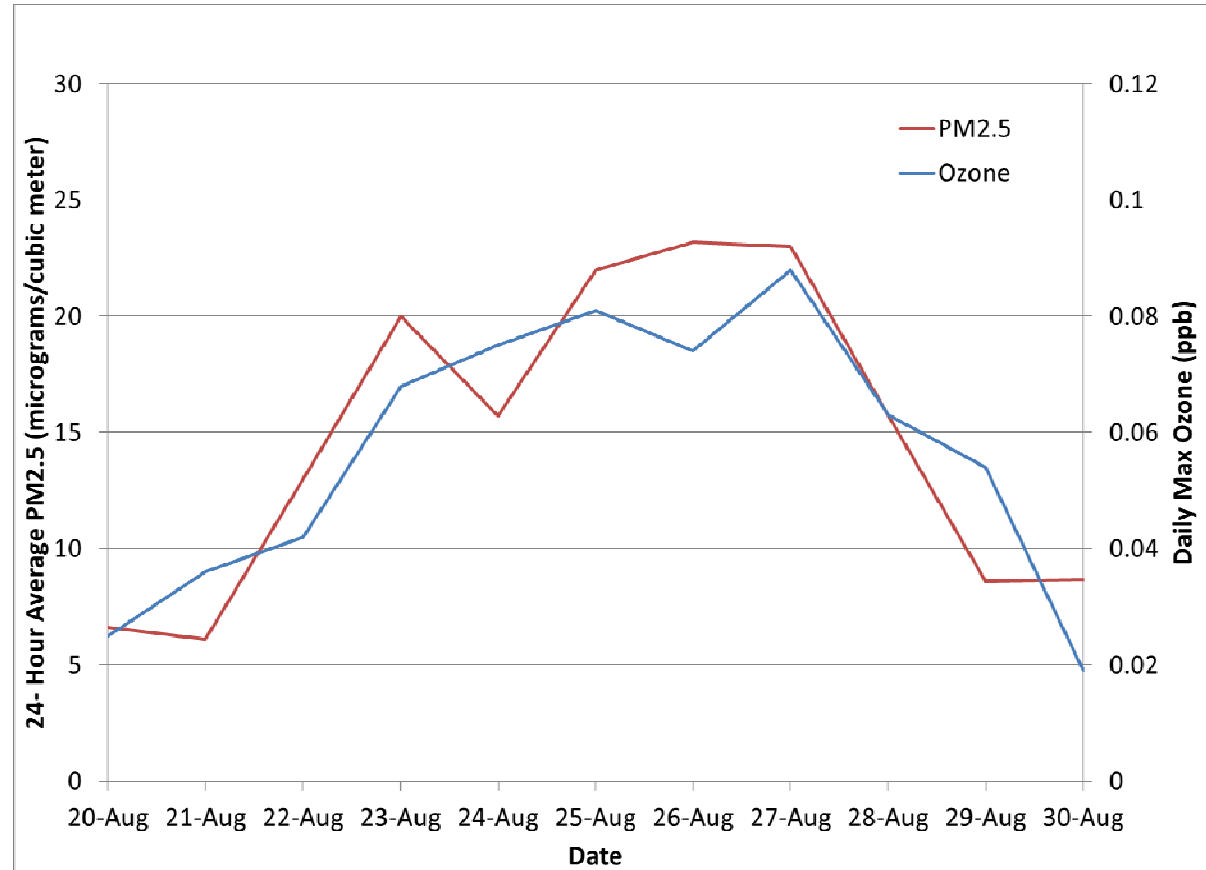
The maximum 8-hour ozone average at the Caddo Valley, AR CASTNet site was the 3<sup>rd</sup> highest of the year (74 ppb)

Daily Maximum 8-Hour Ozone Starting at 11:00 AM CST

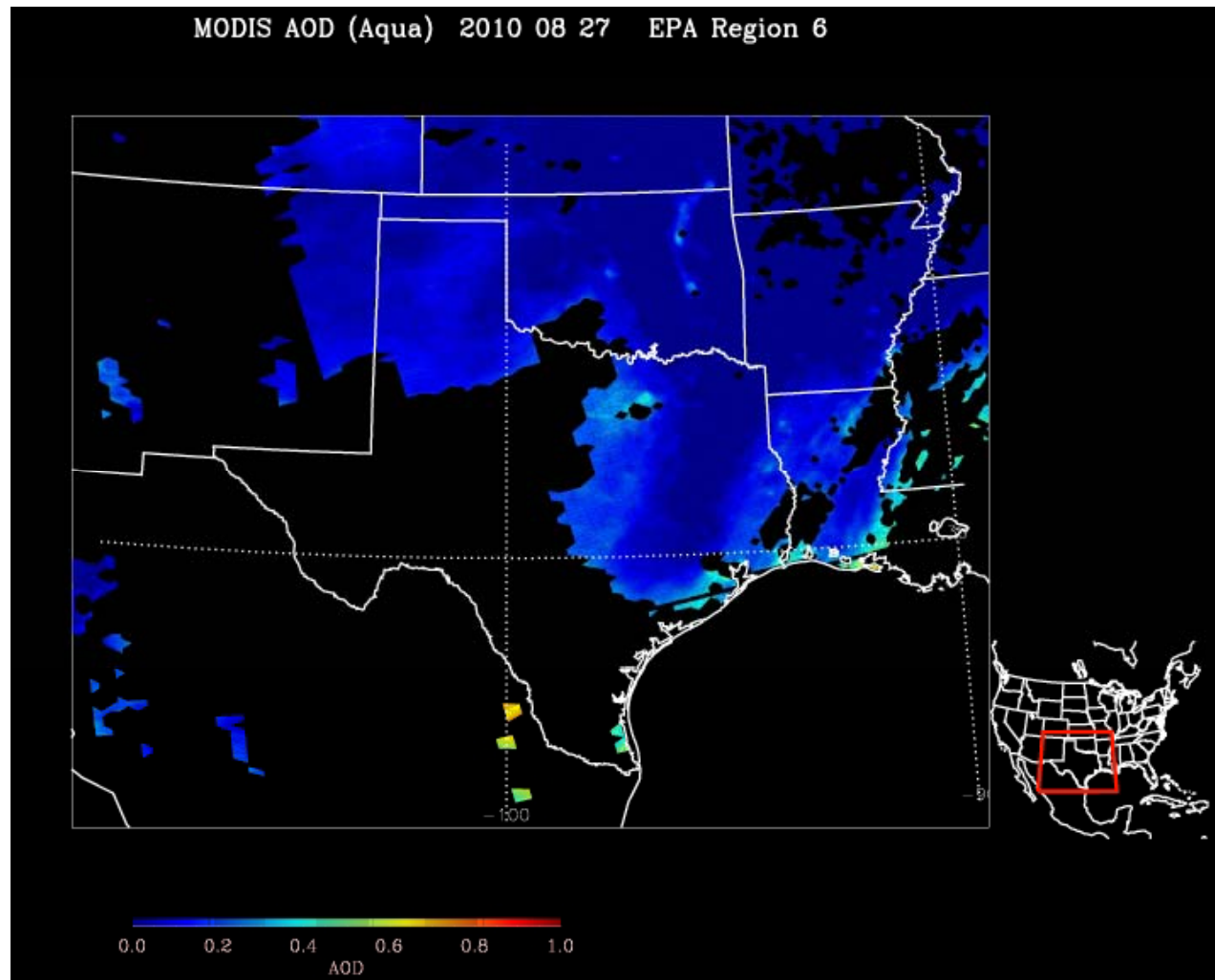


## Multi-Day Episode of Elevated Ozone and PM2.5

- HGB daily maximum 8-hour ozone levels tracked the trend in 24-hour average PM2.5 levels at Clinton Drive during the ramp-up, peak, and dissipation of this regional event.
- PM2.5 levels on August 25-27 were almost twice the annual average.



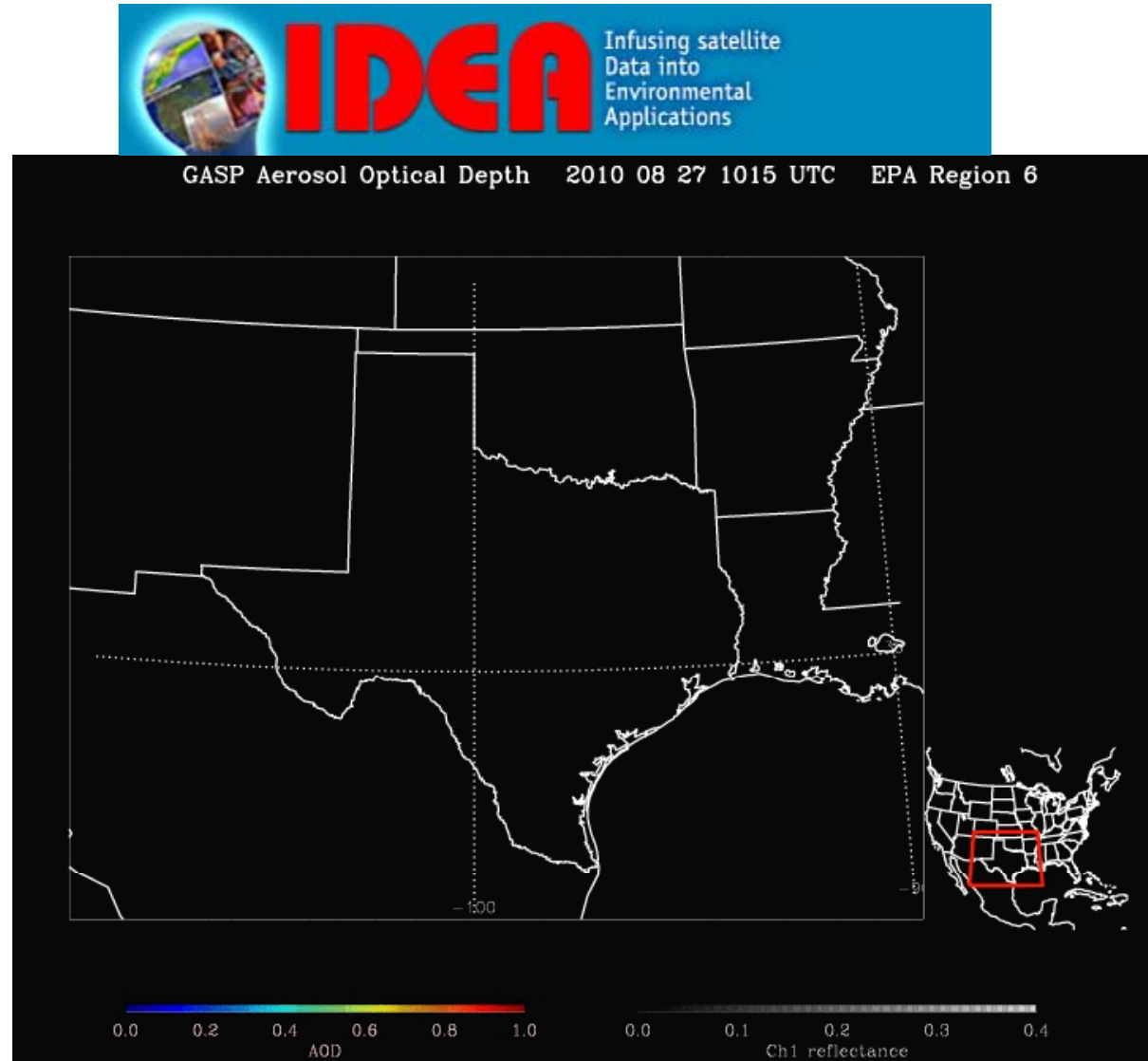
# AQUA MODIS AOD Shows Transport of Haze into East Texas from the NE



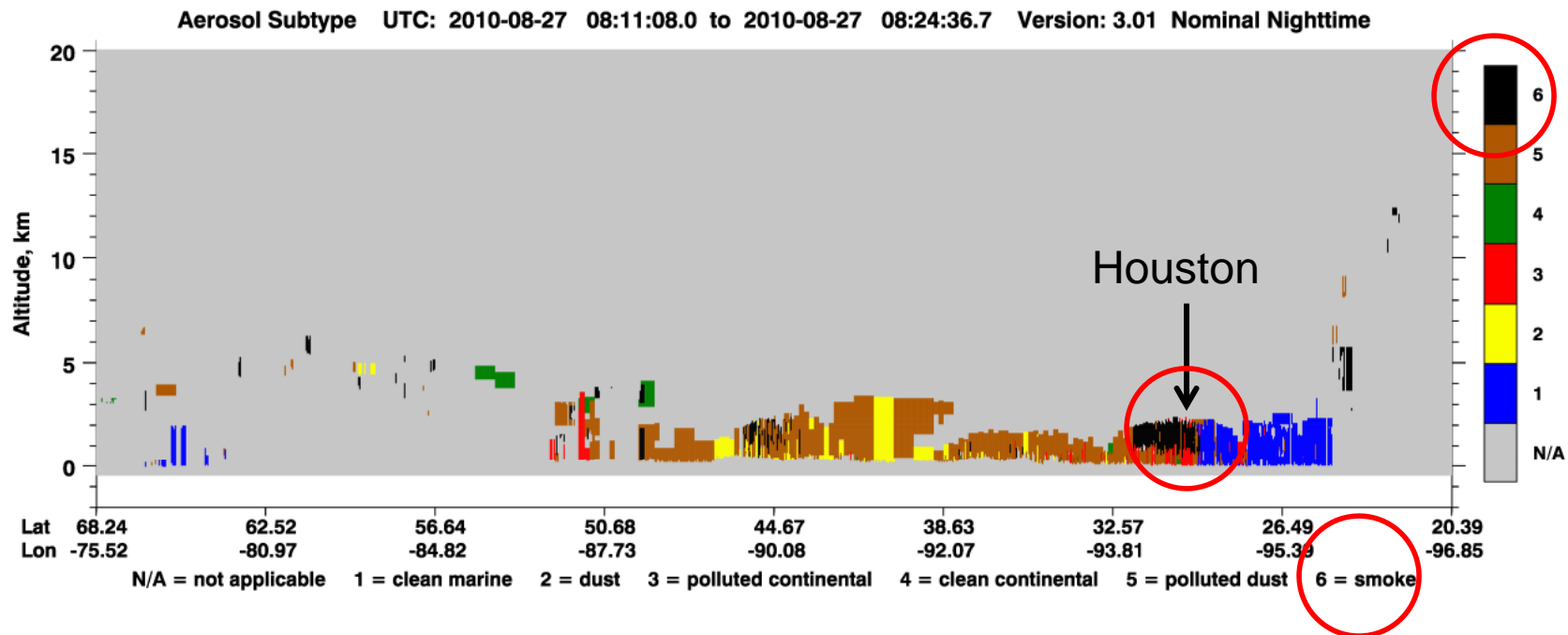
## GASP Aerosol Optical Depth (AOD) Animation Shows Transport of Haze Into East Texas from the Northeast

The animated image shows half-hourly GOES Aerosol/Smoke Product (GASP) aerosol optical depth (in color contours) and half-hourly GOES channel 1 reflectance for cloud (in gray contours) during the sun-lit time.

High AOD was measured over SW Arkansas and NW Louisiana at about 9:00 a.m. CST (1500 UTC) followed by transport of comparatively moderate AOD toward the southwest into and across east Texas (click on the image to view the animation control bar)



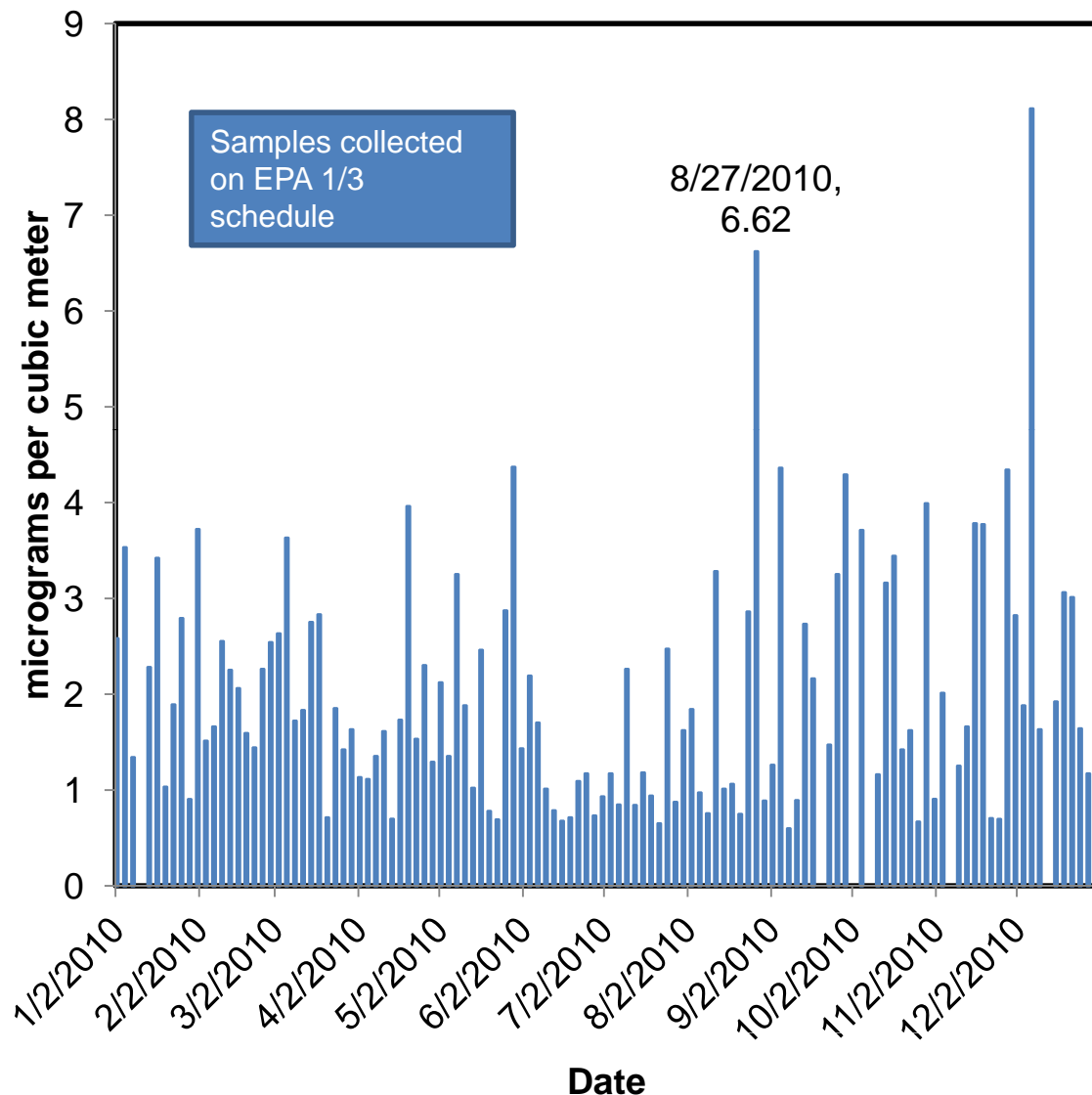
# CALIPSO LIDAR Shows Smoke Mixed with Polluted Continental Air Over Houston





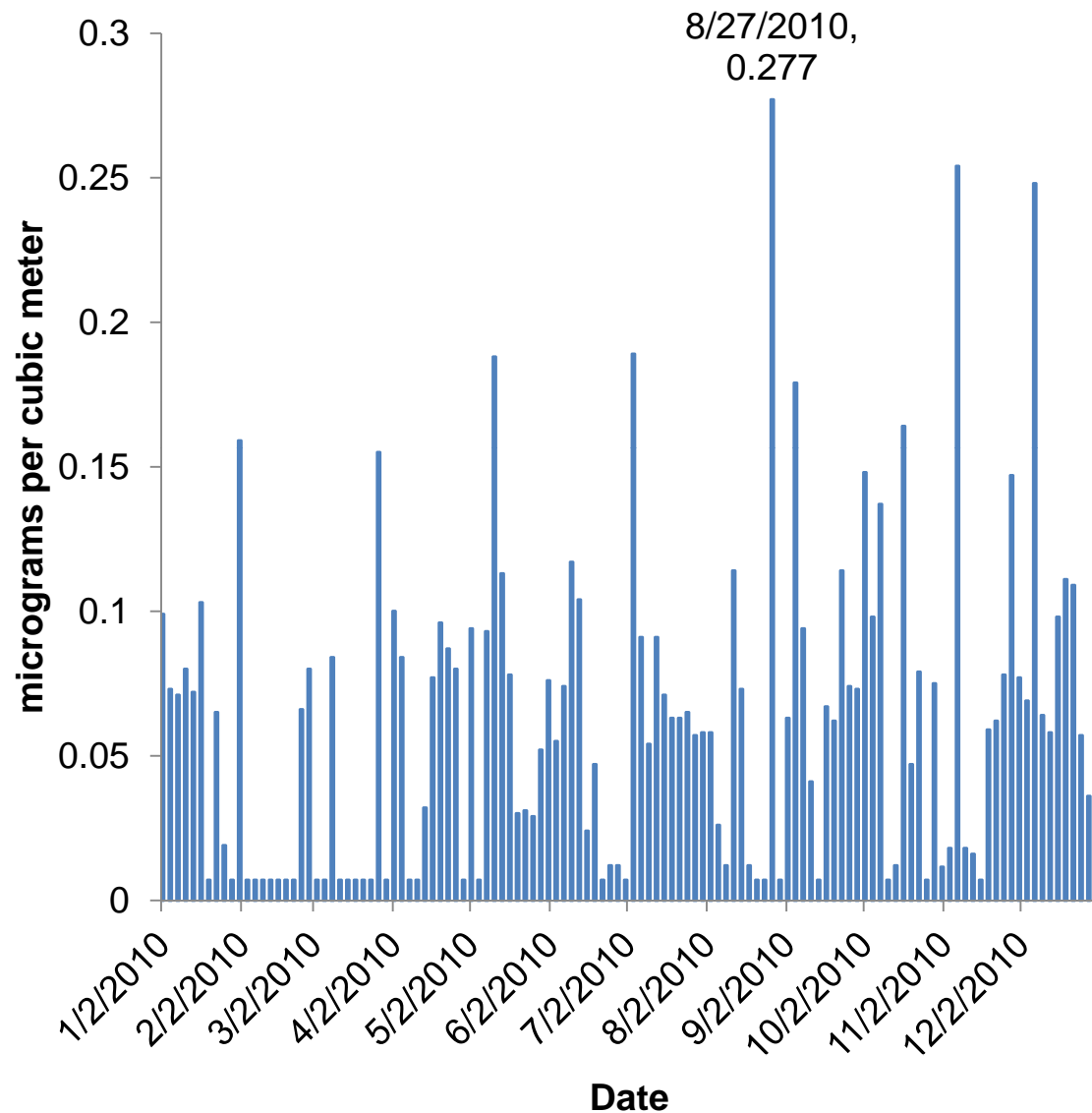
## The Organic Carbon Component of PM<sub>2.5</sub> at the Deer Park STN Site was Exceptionally High

The organic carbon concentration in the PM<sub>2.5</sub> sample collected at the Deer Park Speciation Trends Network Site on August 27, 2010 was the highest of the ozone season and 2<sup>nd</sup> highest of the year.



## The potassium ion Component of PM<sub>2.5</sub> at the Deer Park STN Site was Exceptionally High

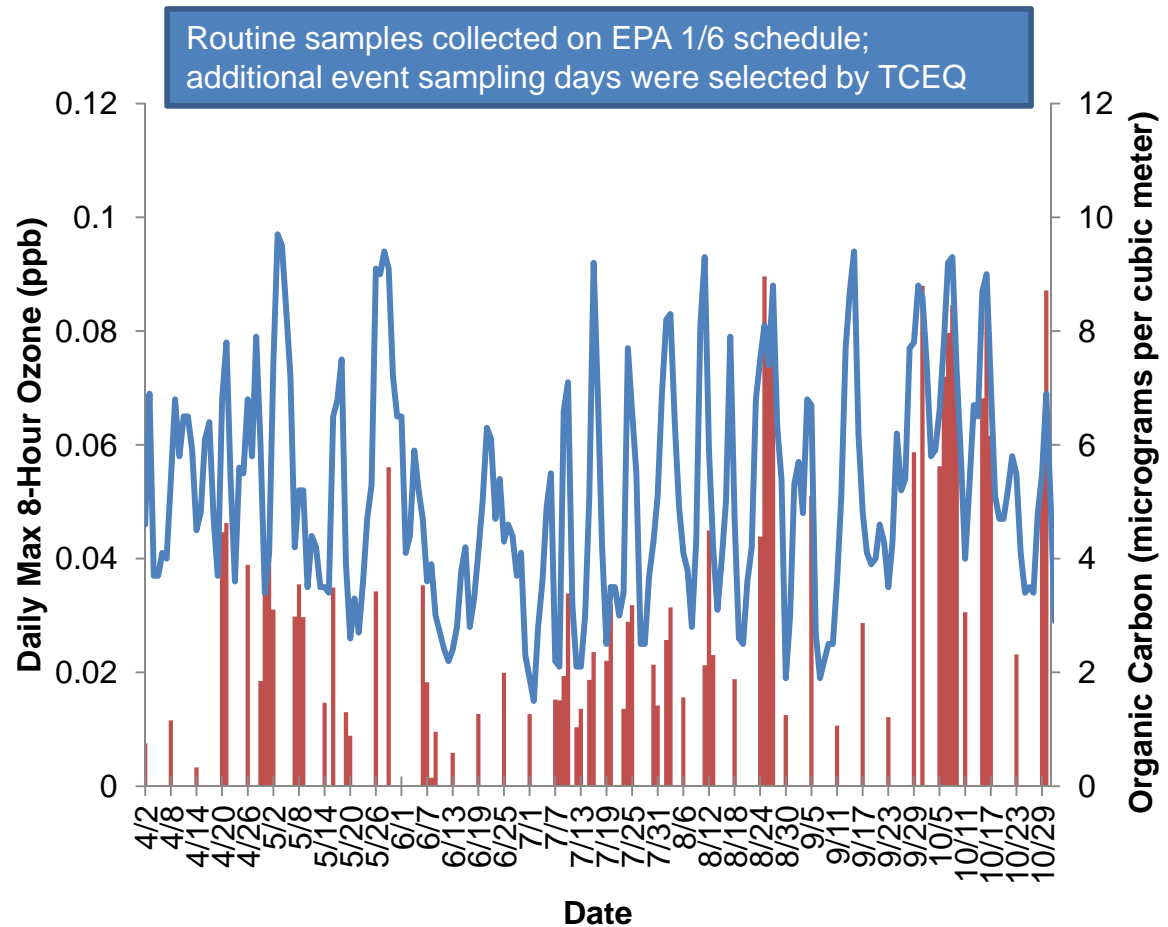
- The K<sup>+</sup> concentration in the PM<sub>2.5</sub> sample collected at Deer Park on August 27, 2010 was the highest of the year.
- The K<sup>+</sup> level on 8/27 was 4.4 times the annual mean.
- K<sup>+</sup> is often used in PM<sub>2.5</sub> source apportionment studies as a tracer for burning biomass.



## The Organic Carbon Content of PM2.5 at Clinton Drive was Exceptionally High

- Organic carbon levels measured August 25, August 26, and August 27 were among the highest of the year.
- Elevated levels were also detected on October 1 and October 6-8, when Houston ozone levels were high and transport was through the Lower MS River Valley.

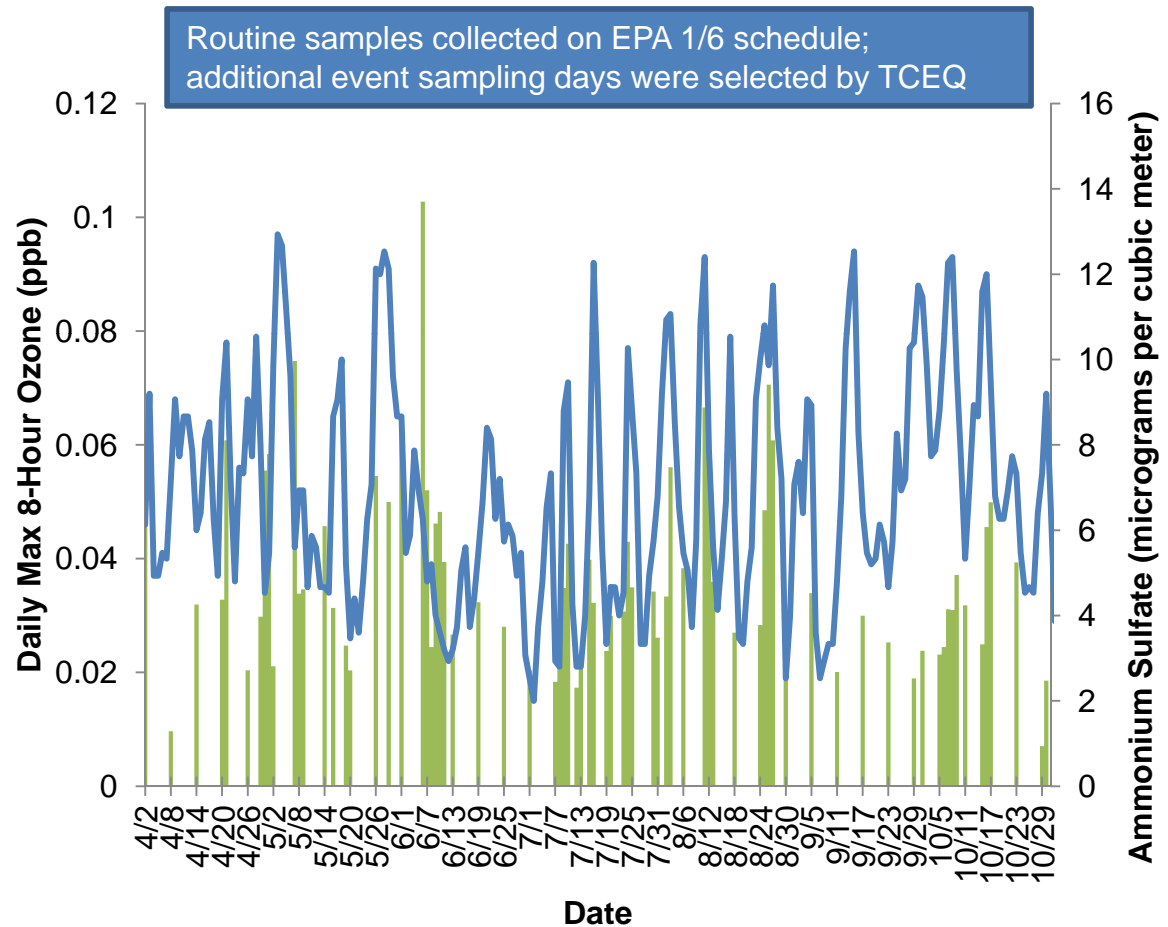
### HGB Daily Maximum 8-Hour Ozone and PM2.5 Organic Carbon



## The Sulfate Component of PM2.5 at Clinton Drive was Also Elevated

- Sulfate levels were elevated on August 27. This is consistent with the NOAA observation that smoke from the Lower Mississippi River Valley was mixed with haze from another source.
- Sulfate was also elevated during several earlier ozone episodes but not during the later smoke episodes.

### HGB Daily Maximum 8-Hour Ozone and PM2.5 Ammonium Sulfate

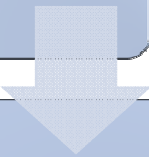


# Summary of Observations (1 of 2)

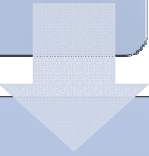
Ozone levels were regionally elevated



There was widespread fire activity in the lower MS River Valley



Wind conditions were favorable for transporting fire emissions to SE Texas



Smoke was detected over SE Texas, extending back to the Lower MS River Valley

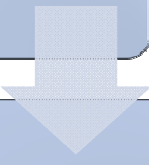


# Summary of Observations (2 of 2)

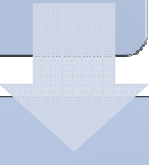
Surface measurements of PM2.5 were elevated



Daily maximum 8-hour ozone levels tracked 24-hour PM2.5 levels during each multi-day event



PM2.5 composition had high levels of organic carbon, water soluble potassium



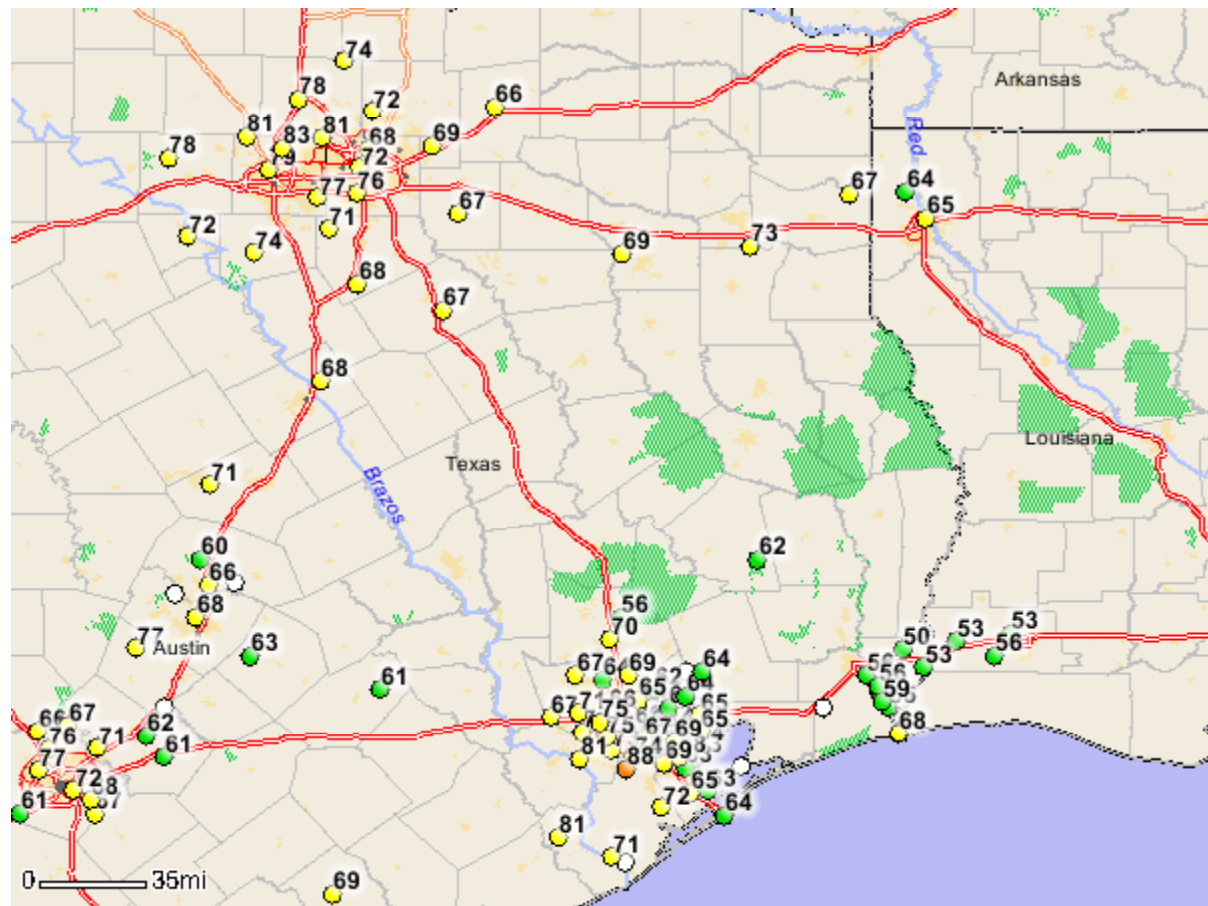
Transported ozone correlated very well with PM2.5 organic carbon but not with sulfate

# 3 Independent Estimates of Fire Impacts

- Background Subtraction
  - Assumed fire impact was equal to ozone levels upwind of Houston minus ozone levels upwind of another east Texas area (BPA or DFW) from where backward trajectories did not pass through area of greatest fire activity
- Linear Regression
  - Used empirical relationship between transported ozone and PM2.5 organic carbon concentration at Clinton Drive
- Surrogate Day Comparison
  - Assumed fire impact was equal to ozone level upwind of Houston minus the ozone level upwind of Houston having similar weather and backward trajectory but no significant fire activity along the trajectory path

## Estimate of the Fires' Impact by Background Subtraction

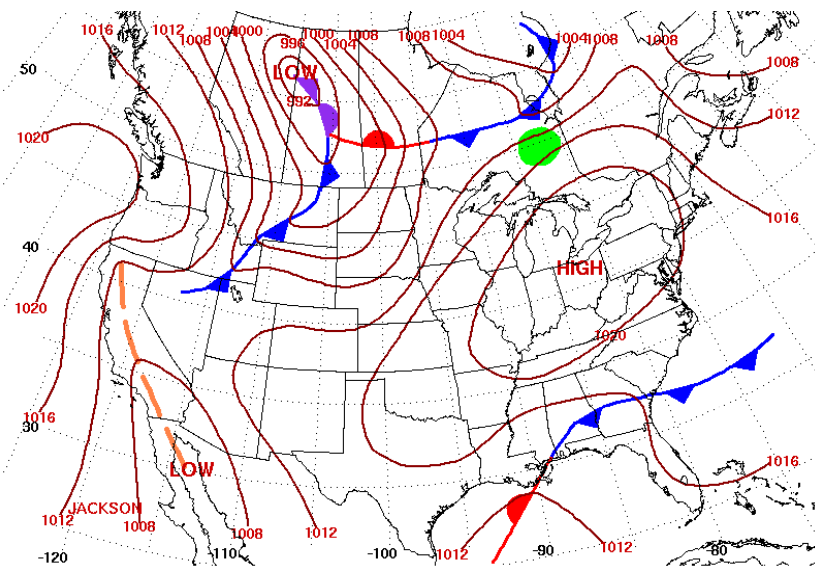
- Background ozone for the 8-hour period beginning 9:00 a.m. CST was about 65 ppb in the air approaching HGB and DFW.
- Background ozone in southeast Texas and southwest Louisiana, which were not in the path downwind of the fires was about 53 ppb.
- The difference between the HGB and BPA background levels, which estimates the fire impact, is about 11 ppb.



# Estimate of the Fires' Impact by Surrogate Day Comparison

August 27, 2010

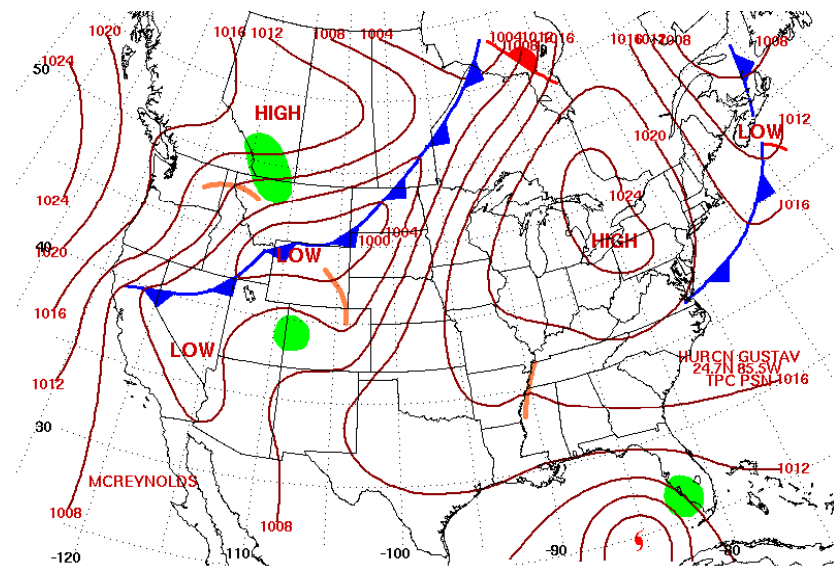
Maximum Temperature = 92 F  
Average Wind Speed = 4.4 mph



Surface Weather Map at 7:00 A.M. E.S.T.

Surrogate Day - August 31, 2008

Maximum Temperature = 92 F  
Average Wind Speed = 4.4 mph



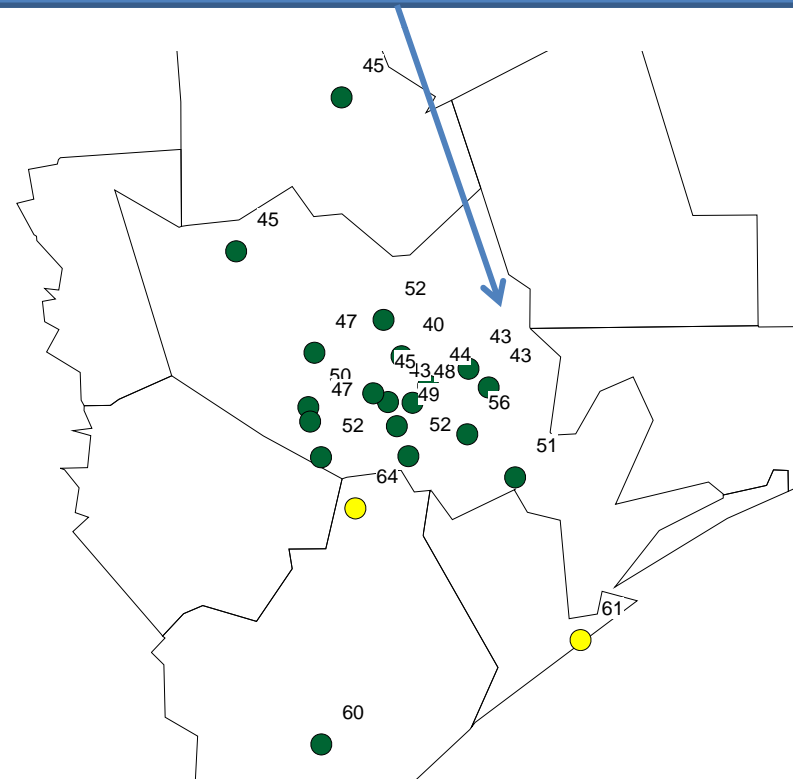
Surface Weather Map at 7:00 A.M. E.S.T.

# August 31, 2008 – Similar Local ozone Production but 21 ppb Less Transport

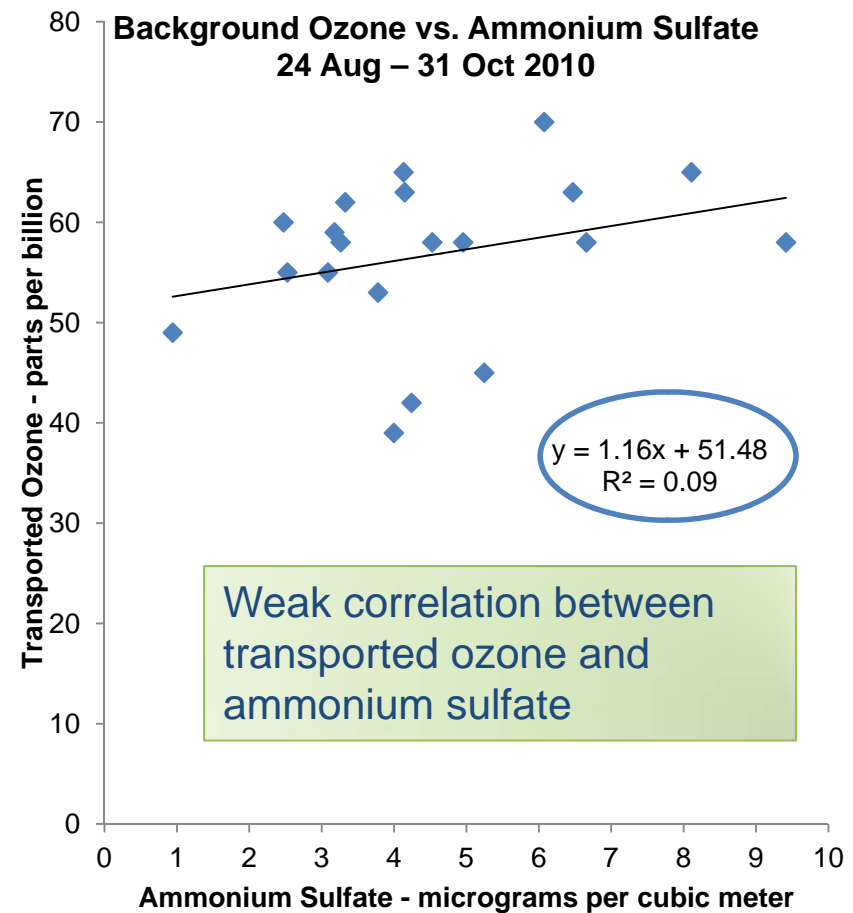
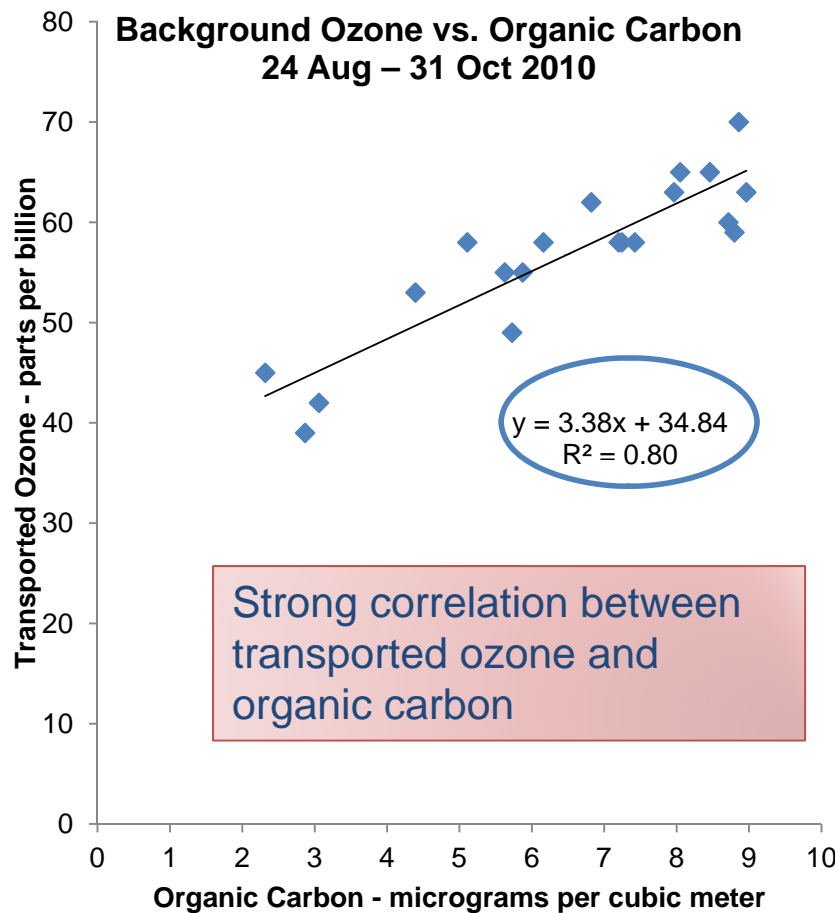
48-Hour Backward Trajectories Terminating at 200m AGL at 2:00 p.m. CST on August 27, 2010 (Yellow) and August 31, 2008 (Green)



Ozone levels transported in from the NE were 43 ppb, compared with 64 on 8/27/2010. The difference, 21 ppb, is an estimate of the fires' impact



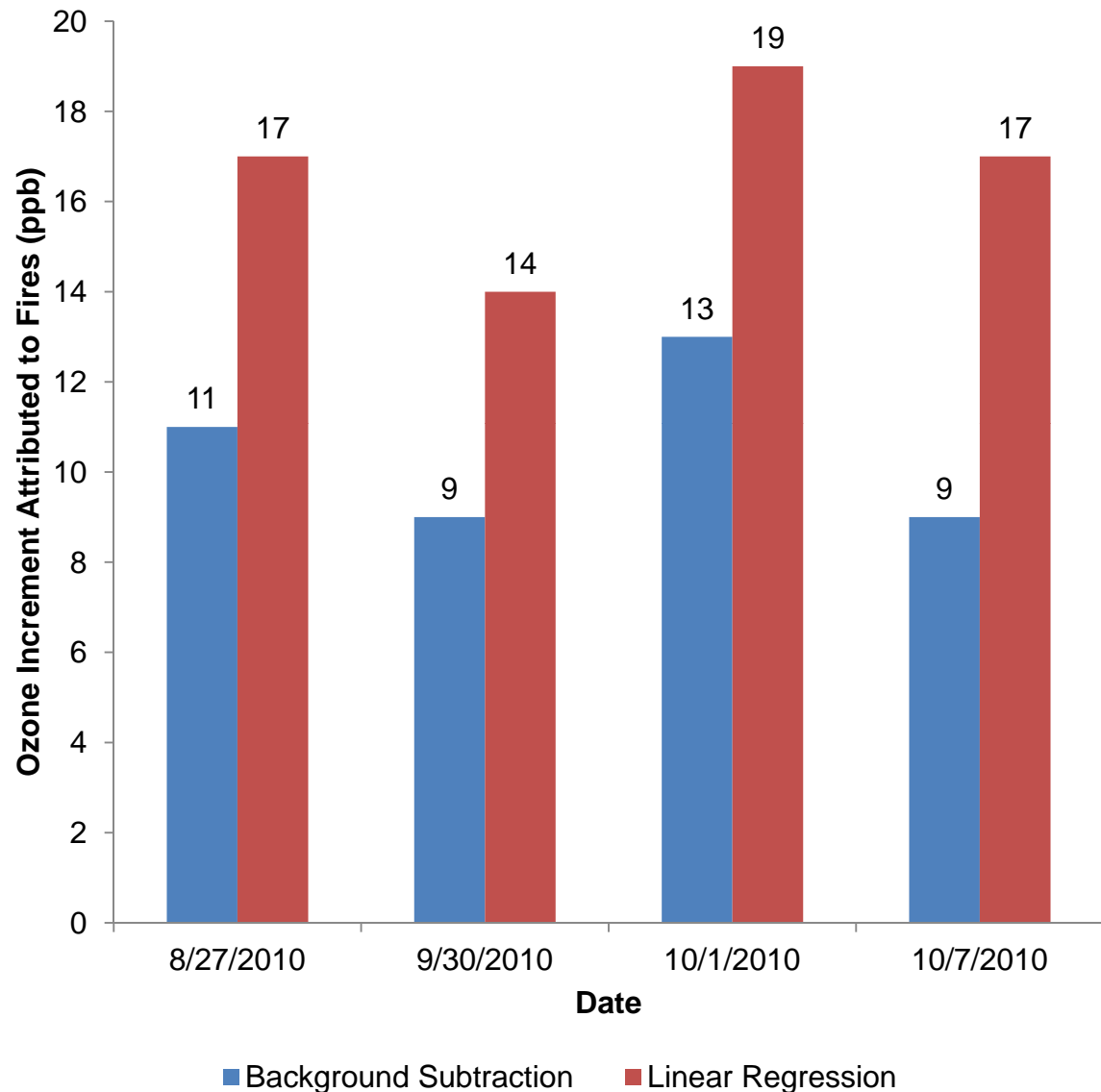
# Estimate of Fires' Impact by Linear Regression



The chart and regression exclude 3 outliers when the background ozone level ranged from 15 – 25 ppb and the organic carbon content was between 1.0 and 1.3 µg/m. With the outliers included, the slope and r-square are 5.0 and 0.83, respectively

## Summary of Fire Impact Estimates for All Case Studies

- Background subtraction and linear regression estimated of fire impacts agree within a factor of 2.
- Surrogate day estimate for August 27 was 21 ppb, also within a factor of 2 of the other methods (surrogate day comparison was not done for the other case studies).





# Conclusions

- Estimates of wildfire impacts on Houston ozone levels for 4 case studies during 27 August – 7 October 2010 range from 9 to 19 ppb
- At CAMS 84, which was the HGB design value monitor for 2008-2010, the annual 4<sup>th</sup> highest daily maximum would be 81 ppb but for the estimated wildfire contributions (the measured 4<sup>th</sup> high was 88 ppb)
- The 7 ppb difference at CAMS 84 that is attributed to the wildfires could be significant with respect to future NAAQS compliance determinations and attainment demonstrations
- CAMS 84 is not unique in this regard; Fire impacts are evident at other monitors on the 4 case study days and on other days that were not analyzed
- Preliminary analyses suggest that 2011 wildfires impacts on ozone levels in Houston, Beaumont-Port Arthur, and other Texas cities may also be significant

# Resources

- NASA Hazard System Fire and Smoke Product Archives
  - <http://www.osdpd.noaa.gov/ml/land/hms.html>
- NOAA HYSPLIT - Hybrid Single Particle Lagrangian Integrated Trajectory Model
  - <http://ready.arl.noaa.gov/HYSPLIT.php>
- EPA AIRNow-Tech
  - <http://airnowtech.org/index.cfm>
- University of Wisconsin MODIS Today
  - <http://ge.ssec.wisc.edu/modis-today/>
- USDA Fire Data in Google Earth
  - <http://activefiremaps.fs.fed.us/googleearth.php>
- NASA CALIPSO LIDAR Browse Images
  - [http://www-calipso.larc.nasa.gov/products/lidar/browse\\_images/show\\_calendar.php](http://www-calipso.larc.nasa.gov/products/lidar/browse_images/show_calendar.php)
- NASA GIOVANNI AIRS Online Visualization and Analysis
  - <http://disc.sci.gsfc.nasa.gov/giovanni>
- EPA AQS Data Mart
  - <http://disc.sci.gsfc.nasa.gov/giovanni>
- TCEQ
  - [http://www.tceq.texas.gov/agency/data/ozone\\_data.html](http://www.tceq.texas.gov/agency/data/ozone_data.html)
- NOAA IDEA
  - <http://www.star.nesdis.noaa.gov/smcd/spb/aq/index.php>
- University of Maryland Baltimore County Smog Blog
  - <http://alg.umbc.edu/usaq/>